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**An audit on technical quality of root fillings performed by undergraduate students**

Fong W, Heidarifar O, Killough S, Lappin M and El Karim I A

Department of Restorative Dentistry, School of Medicine Dentistry and Biomedical Sciences,  
Queen's University Belfast, Belfast, United Kingdom

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**Corresponding author address**

Dr Ikhlas El karim

Department of Restorative Dentistry, School of Medicine Dentistry and Biomedical Sciences,  
Queen's University Belfast, Belfast BT12 6BP, United Kingdom

Email: ielkarim@qub.ac.uk

Tel: +442890637394

**Abstract**

**Aim** To evaluate radiographically the technical quality of root fillings performed by undergraduate dental students and to assess whether students were exposed to an appropriate endodontic case mix during their clinical training.

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**Methodology** A retrospective audit was undertaken evaluating the clinical records of patients who underwent endodontic procedures during the period from September 2015 to June 2016 in the Dental School at Queen's University Belfast, UK. Two final year dental students were trained and calibrated to evaluate post-operative intraoral periapical radiograph of completed root canal treatments using specific assessment criteria. Data was presented as frequencies, percentage and mean  $\pm$  standard deviation (SD). Comparisons of treatment outcomes between groups (posterior and anterior teeth) were calculated using Fisher's Exact Test and the level of significance was set at  $p < 0.05$ . Intra- and inter-examiner reproducibility was assessed by Kappa statistics.

**Results** A total of 222 teeth and 381 canals were assessed and of those 253 (66%) of the root fillings were found to be acceptable in all the assessment parameters namely, taper, length and lateral adaptation of the root filling. Sub-analysis of individual root filling parameters revealed that 372 canals (97%) exhibited good taper, 275 canals (72%) were considered to be of an appropriate length, with 89 canals (23%) found to be underfilled and 17 canals (5%) overfilled. Overall 346 (91%) of canals had good lateral condensation. Students treated both single and multi-rooted teeth and there was no significant association between tooth type and the quality of root filling provided ( $p > 0.05$ ).

**Conclusion** In the majority of the teeth treated by undergraduate students at Queen's University Belfast, the technical quality of the root filling was acceptable and students were exposed to an appropriate case mix for endodontic training.

## **Introduction**

Endodontic treatment is a key component of comprehensive dental care. As retention of natural permanent teeth becomes more commonplace in today's society, general dental practitioners are expected to provide quality endodontic treatment. Prior to graduation undergraduate dental students should demonstrate a sound theoretical knowledge and understanding in endodontics as well as adequate clinical experience during undergraduate training. National and European guidelines recommend that all dental school graduates should be competent at performing root canal treatments

upon graduation. In the UK, the General Dental Council (GDC) requires graduates to 'be competent at a range of procedures in restorative dentistry including endodontic treatment of single- and multi-rooted teeth' (General Dental Council 2008). Similarly, the European Society of Endodontology (ESE) and the Association for Dental Education in Europe published undergraduate curriculum guidelines recommend that undergraduate students should be competent at carrying out good- quality root canal treatment during their undergraduate training (Plasschaert *et al.* 2005, De Moor *et al.* 2013)

The aim of root canal treatment is treatment and prevention of pulpal and periapical disease. The success of this treatment is dependent on appropriate cleaning, shaping and filling of the root canal system and adequate coronal seal (Saunders & Saunders 1994). Therefore, the technical quality of the root filling is an important factor in treatment success (Saunders *et al.* 1997). Indeed, low technical quality root fillings assessed radiographically were found to be associated with post-treatment disease and reduced treatment outcomes (Tavares *et al.* 2009, Ng *et al.* 2008, 2011). Many factors can affect the technical quality of root fillings, such as the length of the root filling material, lateral adaptation to the canal walls and tapered shape. Such factors are often used for radiographic evaluation of root-filled teeth to assess the technical quality of the treatment. On radiographic examination ideally, a good root filling should follow the continuous taper form of the prepared root canal from the coronal aspect to apex, have no voids between the root filling and canal walls, and have an optimal length to within 0.5 to 2 mm distance of the radiographic apex (European Society of Endodontology 2006).

The undergraduate endodontic teaching at Queen's University Belfast is provided over the final three years of the five-year undergraduate course. A preclinical teaching course commences in the first semester of the third year and clinical training starts in the second semester of third year and continues until graduation. ProTaper® Universal nickel-titanium rotary instruments (Dentsply Sirona, Ballaigues, Switzerland) are used in undergraduate training. The endodontic preclinical and clinical teaching is provided by experienced clinical teachers and clinical academics at consultant levels. The preclinical course comprises 30 hours of hands on rotary root canal treatment procedures during which students are required to complete treatment for at least one maxillary central incisor, one

maxillary first premolar, one maxillary 1st molar and 1 mandibular first molar using plastic teeth (T-Endo, Acadental, Lenexa, KS, USA)

The overall aim of this audit was to evaluate undergraduate endodontic education provision in Queen's University Belfast against GDC and European Society of Endodontology (ESE) guidelines. The objectives were to radiographically evaluate the technical quality of root fillings performed by undergraduates and to assess whether students in general were exposed to an appropriate case mix in terms of tooth type and endodontic diagnoses.

### **Materials and Methods**

A retrospective clinical audit was conducted in which the clinical records of 203 patients who had received root canal treatments by undergraduate students at Queen's University Belfast Dental School, UK were evaluated. The following inclusion criteria were applied:

- Primary root canal treatment to a single or multi-rooted permanent tooth
- Treatment undertaken by a 4<sup>th</sup> or 5<sup>th</sup> year undergraduate student under the supervision of a senior clinical staff member between September 2015 – June 2016
- Presence of a post-obturation radiograph showing the entire length of the root and at least 2-3mm of the periapical area beyond the root apex

The exclusion criteria were:

- Treatments where post-obturation radiographs were unavailable.
- Cases where post-obturation radiographs showed superimposition of root canal fillings or over-projection of anatomical structures
- Treatments where only manual instrumentation was used

### **Root canal treatment protocol**

For all primary root canal treatment cases the preoperative radiographs for diagnosis and pre-operative working length determination is required. Treatment commenced with administration of

local anaesthetics and isolation with rubber dam, followed by access cavity preparation, canal cleaning and determination of the working length with periapical radiographs and/or Raypex 5 apex locators (VDW Endodontic Synergy, Munich, Germany) prior to rotary instrumentation using Protaper Universal (Dentsply Sirona). 1% Sodium hypochlorite was the routine irrigant used and in case of multiple visits, 98% calcium hydroxide (Hypo-Cal®, Ellman, NY, USA) was used as an intra-canal medicament. Canal filling was then carried out in the absence of symptoms and infection using matching Protaper® Universal gutta-percha points (Dentsply Sirona) and Tubli-Seal™ (Kerr Dental, Orange, CA, USA). A post-filled radiograph was taken routinely to assess the quality of the root filling followed by placement of a permanent restoration.

#### Assessment of the radiographs

As a gold standard for the technical quality of the root fillings, the (ESE) quality guidelines for endodontic treatment was adopted. According to these guidelines, the prepared root canal should be filled completely unless space is needed for a post, the prepared and filled canal should contain the original canal shape, no space between canal filling and canal wall should be seen and there should be no canal space visible beyond the end-point of the root canal filling (European Society of Endodontology 2006).

The data was collected and compiled into a Microsoft Excel® spreadsheet (Microsoft Corporation, Redmond WA, USA). Digital radiographs were recorded within the Radiology Department at the School of Dentistry and uploaded to Philips IntelliSpace Portal 7.0 (Royal Philips, MX Amsterdam, Netherlands). One orthoradial intraoral radiograph is routinely taken following completion of root canal treatment but in cases of suspected root overlap a second radiograph with different projection is also included. All radiographs were of good diagnostic value and none were excluded from assessment. The method of assessing radiographs was a modified version of the one employed by Balto *et al.* (2010), where the root fillings were evaluated according to length, taper and lateral adaptation parameters (Table 1). A root filling was defined as satisfactory when all three parameters were graded as acceptable. Representative images of the radiographs describing all the possible

outcomes are shown in Figure 1. The radiographs were assessed using the software Philips IntelliSpace Portal 7.0 under optimal viewing conditions. The assessors, two final year undergraduate students (WF and OH), were trained by consultants (IEK and ML) in using the assessment criteria and were calibrated using Cohen's Kappa for intra- and inter-examiner reliability and reproducibility of results. In case of uncertainty the supervisors provided support as required.

### **Statistical analysis**

Data was presented as frequencies, percentage and mean  $\pm$  standard deviation (SD). Comparisons of treatment outcomes between groups (posterior and anterior teeth) were calculated using Fisher's exact test and the level of significance was set at  $p < 0.05$ . Intra- and inter-examiner reproducibility was assessed by Kappa statistics. Each examiner assessed 20 radiographs twice to assess intra-examiner reliability and their assessments were compared for calculation of inter-examiner reliability.

### **Results**

A total of 179 patient records were assessed, with 222 teeth and 381 canals. Males (108) comprised 53.0% of the sample and females (95) comprised 47%. The mean age was  $47.4 \pm 14.7$  years. The fillings were performed by 4<sup>th</sup> and 5<sup>th</sup> year undergraduate students ( $n=95$ ).

The kappa-value for intra examiners reproducibility was 0.77 and 0.74 and of the inter-examiner reliability was 0.856, which are rated as very good (Cohen 1960). According to the assessment criteria the results revealed that 253 (66%) out of the 381 canals assessed were acceptable in all assessment parameters including taper, length and lateral adaptation. Sub-analysis of individual parameters revealed that 372 canals (98%) had good taper and lateral adaptation to canal walls was acceptable in 346 (91%) of canals. 275 canals (72%) considered to have good length with 89 canals (23%) described as under-filled with 17 canals (5%) being overfilled (Table 2).

The endodontic case mix was evaluated in relation to tooth type and endodontic diagnosis. There was a relatively even distribution between anterior, premolar and molar teeth. In terms of quadrant distribution, 60 teeth were in the maxillary right quadrant, 68 teeth were in the maxillary left, 48 teeth were in the mandibular left and 46 teeth were in the mandibular right (Table 3).

The diagnosis of apical periodontitis was found to be the most common cause for root canal treatment, accounting for 46% of all diagnoses, followed by irreversible pulpitis at 40%, periapical abscess (10%) and periodontal-endodontal lesion (2%). The need for elective root canal treatments accounted for 2% of the cases. (Table 3).

Details of treatment protocols are summarised in Table 4. As expected the average number of visits required to completed treatment on posterior teeth was more than for anterior teeth. Various techniques were employed for working length determination: utilising radiographs, apex locators or a combination of the two. In the majority of treatments (88%) sodium hypochlorite was the irrigating solution used. Coronal restorations involved a mixture of direct and indirect restorations. Direct restorations included composites, amalgam and glass ionomer cements. Indirect restorations included crowns, post-retained restorations, inlays, onlays and other lab-made cast restorations. Direct composites were used as final restoration in 49% of cases, comprising the majority of all materials used.

Following analysis of whether the quality of the root filling was related to tooth type, molars and premolars each had a higher percentage of acceptable canals (68% and 67% respectively) when compared to anterior teeth (60%). However statistical comparisons using Fisher's exact test did not reveal any significant differences between the groups ( $p>0.05$ ).

## **Discussion**

Using the ESE guidelines as a benchmark and stringent assessment criteria the results of this audit show that the majority of the root fillings provided by undergraduate students were of acceptable quality when reviewed on an intraoral periapical radiograph. Furthermore, the results also showed that the students performed root canal treatments in both single and multi-rooted teeth. The findings are similar to those reported by Lynch & Burke (2006) who assessed the technical quality of root canal treatment in single-rooted teeth in Ireland and to those of Donnelly *et al.* (2016) who used similar canal preparation technology for root canal treatment to the ones used in the current audit. Results of



similar clinical audits however from other UK dental schools have found acceptable root filling rates as high as 80% and as low as 13% respectively (Hayes *et al* 2001, Pettigrew *et al.* 2007). Similarly, conflicting findings were also reported by other studies from Europe and internationally (Balto *et al.* 2010, Khabbaz *et al.* 2010, Unal *et al.* 2011, Elsayed *et al.* 2011). Some of these variations may reflect differences in teaching and training but could also be due to the use of different methods and assessment criteria for radiograph evaluation. For instance, Unal *et al.* (2011) and Khabbaz *et al.* (2010) used a qualitative method of assessing radiographs, categorising length and homogeneity into “acceptable” and “unacceptable” to determine whether root fillings could be considered as good quality, whereas Balto *et al.* (2010) assessed root filling length, homogeneity and canal taper. The present assessment criteria focused on the three essential parameters of length, taper and lateral adaptation. In addition to this, the study benefitted from the use of digital radiographs and software that facilitated viewing images in optimal conditions. The software also allowed for accurate measurement of the root length, reducing the chance of errors in calculating the distance from the root apex. However, periapical radiographs have limitations in assessing quality of roots fillings in a bucco-lingual direction unless supplemented with parallax views and such a protocol was not routinely applied for all the radiographs assessed in this audit.

More in-depth analysis of the results for individual assessment parameters revealed that taper was the best performing parameter, with 98% of canals classed acceptable. This is perhaps not surprising as the students used ProTaper® Universal nickel-titanium rotary instruments (Dentsply Sirona). Canals prepared with ProTaper instruments have been found to maintain better curvature and have fewer aberrations compared with those prepared with hand files (Yang *et al.* 2007). The lateral adaptation parameter was not performed as well as taper, despite the fact that following canal preparation in all cases canal filling was undertaken using matching ProTaper® gutta-percha points. This could be due to variations in canal anatomy and degree of taper resulting in adequate preparation and cone fit in the apical compared to the coronal part of the root canal.

The most poorly achieved parameter was the proximity of root canal filling to the radiographic apex (length), with 72% of canals filled to an acceptable length. There are numerous potential reasons for the underfilling of root canals. The radiographic evaluation undertaken in this study could not account for anatomical factors such as canal sclerosis. Overfilled root canal fillings are most commonly due to over instrumentation and inability to provide a proper taper (Torabinejad & Walton 2002) and as such was observed in a much lower rate than underfilled root canals. A number of techniques were employed for determination of the working length, including radiographs, apex locators (Raypex 5, VDW Endodontic Synergy) or a combination of both. Radiographs are traditionally used for working length determination and the apex locators may provide more accurate location of the apical constriction. However, recent evidence suggests that the precision of electronic working length measurement depends on the device used and the type of irrigant (Tsesis *et al.* 2015); therefore, the combined use of radiographs and apex locators may be advantageous. The fact that an apex locator alone was used in 19% of cases for working length determination could account for some of the variability in the results obtained in the length parameter. It is hoped that more emphasis will be placed on educating students in this area, which should result in a higher number of treatments achieving a working length within 0.5-2mm of the radiographic apex.

Both The GDC and ESE guidelines require undergraduate students to be competent in root canal treatment in both single and multi-rooted teeth. As shown in Table 3 the students in Belfast are exposed to reasonable mix of single and multi-rooted teeth. Moreover, when assessing the quality of root fillings for each tooth type there was no significant difference between single and multi-rooted teeth. Anterior root canals (incisors and canines) illustrated an acceptability rate of 61%, posterior root canals were acceptable in 67% of cases for premolars and 68% for molars. These results are in contrast with several previous studies (Chueh *et al.* 2003, Kumar & Duncan 2012), which demonstrated that anterior teeth tend to have better quality root fillings than posterior teeth. In general, anterior teeth and premolars have larger, straighter and fewer root canals than molars. Therefore, an anterior tooth or a premolar is easier to treat than a molar, where a higher technical quality of root filling would be expected. The results showed that the quality of the root fillings is not

different whether performed on anterior or posterior tooth and this may be related to the use of rotary NiTi instrumentation as shown by Donnelly *et al.* (2016) where the treatment outcome for posterior teeth has improved with the introduction of such technology. However, it is also likely that the limitation of periapical radiographs in assessing the quality of root fillings in posterior teeth may have overestimated the outcome compared to anterior teeth. Future work using more accurate imaging technologies such as CBCT may be useful in this regard.

## Conclusion

The quality of root fillings performed by undergraduate students in the School of Dentistry at Queen's University Belfast, UK were acceptable in 66% of cases. The students also were exposed to appropriate case mix in terms of tooth type and clinical diagnosis. Although the technical quality in terms of lateral adaptation and taper of root canal fillings was found to be acceptable, improvement in quality of root filling length is desirable.

## Conflict of Interest statement

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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### Figure Legend

**Figure 1** Representative radiographs of the parameters assessed in the audit according to criteria outlined in table 1; (A) overfilled root, (B) acceptable length, density and taper (C) under-filled root and (D) unacceptable density

**Table 1** Summary of assessment criteria used for evaluation of the radiographs for technical quality of the root filling (adopted with modification from Balto *et al.* 2012)

Parameter	Length		Lateral adaptation		Taper	
Criteria	Acceptable	Unacceptable	Acceptable	Unacceptable	Acceptable	Unacceptable
	Root filling terminating 0-2mm from radiographic apex	Root filling extending beyond the radiographic apex (Overfilled) or $\geq 2$ mm away from apex (under filled)	Voids absent, homogenous root filling, good condensation	Voids present, heterogeneous root filling, poor condensation	Consistent taper from orifice to apex	No consistent taper from orifice to apex

**Table 2** Sub analysis of individual parameters of length, lateral condensation and taper revealed slight variations

Parameter	Length			Lateral adaptation		Taper	
	Under-filled	Acceptable	Overfilled	Acceptable	Unacceptable	Acceptable	Unacceptable
Number	89	275 (72.2%)	17 (4.5%)	346	35 (9.2%)	372	9 (2.4%)
of canals	(23.3%)			(90.8%)		(97.6%)	

**Table 3** Tooth type and endodontic diagnosis for root fillings evaluated in the audit

Tooth type							
Anterior		Premolar		Molar		Total	
Teeth	Canals	Teeth	Canals	Teeth	Canals	Teeth	Canals
74	74	71	90	77	217	222	381
Diagnosis							
Apical periodontitis	Irreversible pulpitis	Periapical abscess		Elective RCT		Perio-endo lesion	
102	90	21		5		4	

**Table 4** Summary of endodontic protocols employed by student during the course of root canal treatment (NaOCl, sodium hypochlorite, AL; apex locator, Comps; composite). \*The mean is average of visits is per patient. The percentage is for al treated canals

Number of visits		Irrigant		Working length			Final restoration		
Ant	post	NaOCl	other	Radio	AL	Both	Comps	Indirect rest	other
2±0.8 SD	3±1 SD	88%	12%	43%	19%	38%	51%	24%	28%

**Table 5** Quality of root filling according to tooth type

Tooth type	Acceptable	Unacceptable	Total canals
Anterior	45 (60.8)	29 (39.2)	74
Premolar	60 (66.7)	30 (33.3)	90
Molar	148 (68.2)	69 (31.8)	217
Total	253	128	381





Fig 1